CLIMATES OF FESCUE GRASSLANDS OF MOUNTAINS IN THE WESTERN UNITED STATES

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Abstract.— Climates of fescue grasslands were described by summarizing USDC Weather Bureau records of representative sites. Mean temperatures of the warmest month declined from 18 to 14 C, average annual precipitation increased from 40–50 to 170 cm, and the number of arid months in an arbitrarily defined dry year declined from 3 to 1–2 as one moves from *Festuca arizonica* (14 stations) to *F. scabrella* (15) to *F. idahoensis* (17) to *F. thurberi* (6) to *F. viridula* (9). Climates of the grasslands are sufficiently like those of the *Pseudotsuga menziesii* and *Abies lasiocarpa* zones of the northern Rocky Mountains to make one ask what factors—wind, snow duration, soil characteristics, or fire—allow the fescue grasslands to persist in a conifer climatic zone.

Fescue grasslands form an important part of mountain vegetation in the western United States. The geographical and altitudinal ranges of major species are shown by Hitchcock (1950) and Kuchler (1964) among others. *Festuca arizonica* Vasey occurs in the southern Rocky Mountains under pine forests or in meadows in Kuchler's types 18 and 19. *Festuca thurberi* Vasey is found in higher forests to timberline in the southern and central Rocky Mountains. *Festuca scabrella* Torr. and *Festuca idahoensis* Elmer occur in the northern Rocky Mountains in Kuchler's foothill grassland (63) type as well as in meadows in the forest zone. *Festuca viridula* Vasey is generally found west of the Rocky Mountains in alpine and subalpine meadows, above the ranges of *Festuca scabrella* and *Festuca idahoensis*.

The objects of this paper are (1) to summarize data available for USDC Weather Bureau stations (6 to 17) in each grassland type and (2) to compare the climates of the fescue grasslands. Climates of adjacent vegetation types have been summarized by similar methods (Weaver 1979). Other studies of the climates of fescue grasslands include a 3-year study of summer climates of two *Festuca scabrella* grasslands in British Columbia (vanRyswyk et al. 1966), a 5 (now 10-)-year study of growing season climates of four *Festuca idahoensis* grasslands in southwest Montana (Mueggler 1971), and a 23-year study of climate effects in a *Festuca idahoensis* stand in south Idaho (Blaisdell 1958).

Methods

Maps of weather station locations were sent to U.S. Forest Service and University personnel familiar with fescue grasslands, along with letters asking each to identify weather stations which lay in that person's fescue type. I gratefully acknowledge the help of E. Aldon, W. Clary, and W. Moir with *F. arizonica* stations; of P. Currie, W. Moir, H. Paulsen, and G. Turner with *F. thurberi* stations; of M. Morris with *F. scabrella* stations; of M. Morris, W. Mueggler, and G. Payne with *F. idahoensis* stations; and J. Strickler with *F. viridula* stations. A few of the sites studied were not visited by those recommending them, but the availability of herbarium material from the sites and the small between-site standard errors (less than the between-year standard errors for a station in the type) suggest that there were few or no misclassifications.

The 1961–1970 climatological data (USDC 1961–1970) for each station were summarized by calculating the mean and standard errors for monthly precipitation, average monthly maximum temperature, average monthly minimum temperature, and monthly frost days. These were returned to the cooperators for comment. A relatively short peri-

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od of record was used (1) because it seemed wise to compare all stations for the same period, (2) because many stations lacked a longer record, and (3) because without containment the number of data points involved would have become unmanageable; 490 data points were collected for each of the 61 stations considered in this study.

A grand summary of the climatological data was made by calculating average means and average standard errors across the stations in each type. These data, along with those of the driest and wettest station in each type, are summarized in Figure 1. The driest and wettest station in each type were chosen arbitrarily as those with the lowest and highest average annual precipitation.

The weather stations used were: (1) For *Festuca arizonica*, Chevlon RS, Flagstaff, Fort Valley, Grand Canyon, Jacob Lake, and McNary, Arizona; Pagosa Springs and Red Feather Lakes, Colorado; and Gascon, Lake Maloya, Los Alamos, Luna RS, Ruidoso, and Wolf Canyon, New Mexico. (2) For *Festuca*

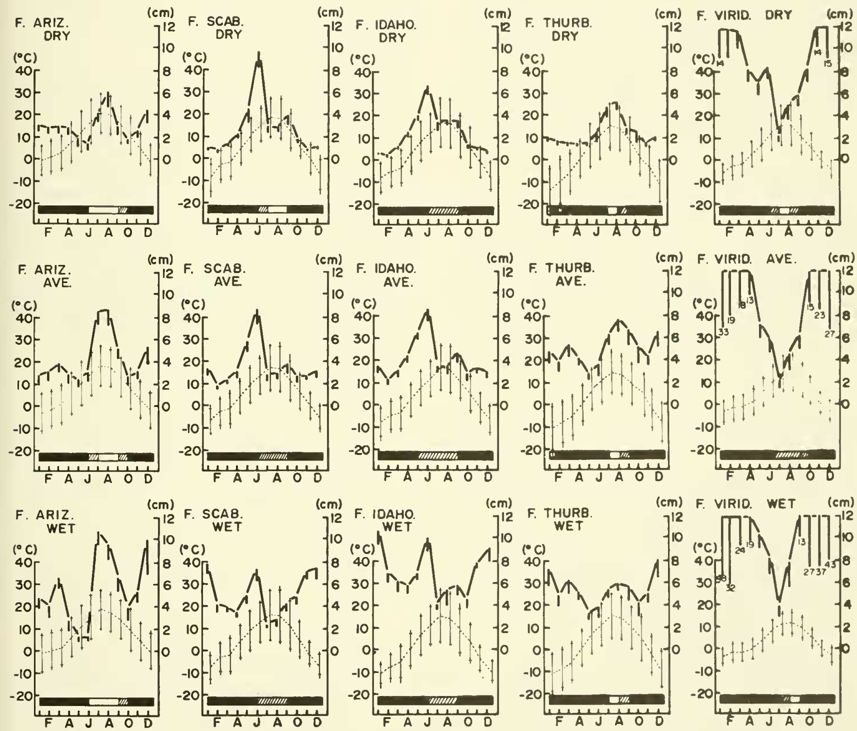

Fig. 1. Climates of fescue grasslands 1961–1970. The dashed line shows the annual course of mean daily temperature; bars reaching above and below it show mean monthly maximum and minimum temperatures; and short bars reaching beyond the cross bars show the mean standard errors of the maximum and minimum. The heavy solid line indicates mean monthly precipitation and heavy bars extending below this line show the standard errors of these means; associated numbers in the *F. viridula* graphs indicate precipitation levels that lie off the graphs. Arid months (Walter, 1973) are those in which the temperature line rises above the precipitation line. The heavy bar across the base of the graph indicates the number of frost (0 C) days: clear months experience less than one frost per month, hatched months experience from one to six frosts, and solid months experience more than six frosts.

thurberi, Cochetopa Creek, Crested Butte, Silverton, Taylor Park, Telluride, and Wolf Creek Pass, Colorado. (3) For *Festuca scabrella*, Babb, Browning, Del Bonito, Elliston, Gibson Dam, Gold Butte, Kalispell, Lewiston, Lincoln, Ovando, Phillipsburg, Polebridge, Polson, St. Ignatius, and Sula, Montana. (4) For *Festuca idahoensis*, Bozeman MSU, Gallatin Gateway, Hebgen Dam, Jackson, Lakeview, Lima, Melville, Mystic Lake, Pony, Red Lodge, Virginia City, White Sulphur Springs, and Wisdom, Montana; Buffalo 15SW, Burgess Junction, Lamar RS, Wyoming, and Kilgore, Idaho. Powder River Pass, Soldier Park, and Willow Park, Wyoming (J. Thilenius); Plummer 3WSW, Moscow, Grangeville, Hill City, Fairfield 8S, and Three Creek, Idaho (M. Hironaka); Dayton, Lacrosse, Pomeroy, Walla Walla, Cheney, Moscow, Pullman, Rosalia, and Goldendale, Washington (Daubenmire 1970); and Bangtail Ridge, Montana, could probably have been included but were not. (5) For *Festuca viridula*, Soda Springs, Squaw Valley, Twin Lakes, California; Crater Lake and Santiam Pass, Oregon; Rainier Paradise RS and Stevens Point, Washington; and Burke, Idaho. Summer precipitation data for additional stations, usually maintained by the U.S. Forest Service, are recorded in USDC Climatological Data records.

RESULTS

It was noted earlier that in the southern Rocky Mountains one finds *F. arizonica* at the lower edge of the forest zone and that in higher forests and meadows one finds *F. thurberi*; in the northern Rocky Mountains, *F. idahoensis* and *F. scabrella* range from foothill grasslands to mountain meadows; west of the Rocky Mountains one may find *F. viridula* in alpine and subalpine meadows above the normal range of either *F. idahoensis* or *F. scabrella*.

The following paragraphs, as well as Table 1 and Figure 1, point out similarities and differences in the climates of the grasslands occupied by these species. The discussion emphasizes an average climate calculated from measurements made at 6 to 17 weather stations. The average climate for a type will tend to underestimate precipitation and frost days and to overestimate temperatures because relatively high and inaccessable sites usually lack weather stations. For this reason, the reader should consider carefully the cli-

TABLE 1. Mean climatic characteristic of fescue grasslands.

	F. arizonica	*F. scabrella*	*F. idahoensis*	*F. thurberi*	*F. viridula*
Number of stations	14	15	17	6	9
Mean temp., coolest month (C)	–3	–6	–8	–10	–3
Daily range (C)	17	11	12	20	9
Months with less than six frosts	4	3	4	2	4
Mean temp. of coolest frostfree month (C)	13	13	8	12	10
Mean temp., warmest month (C)	18	17	17	14	14
Daily range (C)	17	20	20	19	16
Mean SE of maximum temperatures					
Between years	0.6	0.8	0.7	0.6	0.6
Between stations	0.5	0.3	0.6	1.0	0.8
Mean SE of minimum temperatures					
Between years	0.5	0.6	0.6	0.5	0.5
Between stations	0.7	0.5	0.6	0.7	0.4
Number of arid months					
Mean	0	2	0	0	1
Dry year	3	3	2	1	2
Average annual precipitation (cm)	51	43	48	61	170
Mean SE of precipitation (mm)					
Between years	9	7	6	9	25
Between stations	4	3	4	9	15

matic ranges demonstrated by data from extreme stands (Fig. 1).

Regardless of vegetation type average winter air temperature in weather shelters at heights of 1 to 2 m are in the –3 to –10 C range. Night temperatures are 5–10 C cooler than this, and day temperatures are 5–10 C warmer. The daily range is proportional to the distance from the Pacific Ocean, i.e., to continentality. Herbaceous plants and small animals in fescue grasslands usually experience winter temperatures varying only slightly around 0 C because a snow layer insulates them from cold air masses.

The "frost-free" season is from two to four months long in a fescue grassland: For *F. thurberi* it is two months, for *F. scabrella* it is three months; and for the remaining fescues it is from three to four months.

Cooler months in the frost-free season have average temperatures of 8–13 C. Warmer months in this period have average temperatures of 17–18 C in the lower *F. arizonica*, *F. scabrella*, and *F. idahoensis* sites and 14 C in the higher *F. thurberi* and *F. viridula* sites. Nightly minimum temperatures average 8–10 cooler and maximum temperatures are 8–10 C warmer than average temperatures.

The average standard errors of daily maximum temperatures taken a month at a time are 0.7 between years and 0.6 between stations. The average standard errors of daily minimum temperatures taken a month at a time are 0.5 between years and 0.6 between stations. The fact that between-year variability exceeds between-station variability is an indication of the homogeneity of temperature data gathered in each vegetation type. Temperatures deviating more than two standard errors from the mean are improbable (3 percent).

In an average year *F. scabrella* experiences two arid months, *F. viridula* experiences one arid month, and the remaining fescues experience no arid months; during these months plant growth is especially dependent on water stored in the soil profile during the preceeding months. This statement depends on the definition of an arid month as one in which the temperature line, on a graph plotted with the scales used, rises above the precipitation line; this device was developed by H. Walter (1973) and similar devices are discussed by Daubenmire (1956). Note that if one uses Walter's index the length of arid periods are the same for the driest, the average, and the wettest stand considered in each type, except for *F. arizonica* (dry) and *F. viridula* (wet).

A "dry year" may be defined as one in which precipitation is always two standard errors below the mean, because the probability of such low precipitation in one month is about 3 percent. Such a year for the average fescue stand in a type would be drier than the dry stand presented for that type, with the exception of the dry *F. arizonica* stand. In such a dry year arid months experienced in the frost-free season would be two for *F. scabrella*, *F. idahoensis*, and *F. viridula*; one for *F. arizonica*; and none for *F. thurberi*. Total arid months experienced would be three for *F. arizonica* and *F. scabrella*, two for *F. idahoensis* and *F. viridula*, and one for *F. thurberi*.

Total precipitation ranges from 43 cm in the *F. scabrella* type to 177 cm in the *F. viridula* type, but total precipitation is a poor indicator of water availability during the growing season. This is shown by two facts: first, the fescue types with the greatest number of arid months (as defined by Walter, 1973) during an average year include the driest type (*F. scabrella*) and the wettest type (*F. viridula*), the latter because it receives much of its precipitation during the winter months. Deep, fine-textured soils may compensate for this type of aridity if winter precipitation brings them to field capacity. And, second, within each type the wettest stand differs from both the dry and the average stand by the relatively great amounts of precipitation it receives during the winter months.

CONCLUSIONS

A review of climatic data from 61 weather stations representing five fescue grassland types and spanning 25 degrees of latitude leads one to three qualified conclusions. (1) Variation in climate between sites in a fescue grassland type is usually less than variation between years at a site in that type. (2) The climates of fescue grasslands are generally similar, with mean temperatures in the coldest month between –3 and –10 C, mean temperatures in the warmest month between 14 and 18 C, daily temperature ranges of about 18 degrees, two to four months with fewer than six frost days, and months in which evapotranspiration exceeds precipitation usually less than two. (3) Ecologically important differences between the climates of the fescue types lie in summer conditions. Average July temperatures are higher *F. arizonica, F. scabrella,* and *F. idahoensis* grasslands (17–18 C) than in *F. thurberi* and *F. viridula* grasslands (14 C). And arid months decline from three in *F. arizonica* and *F. scabrella* to 1 or 2 in *F. idahoensis, F. thurberi,* and *F. viridula* grasslands.

A comparison of the fescue climate with that of other vegetation types of the northern Rocky Mountains (Weaver 1979) shows that the fescue grasslands generally appear in a coniferous forest climate: (1) its frost-free season is similar to that of *Pseudotsuga menziesii* and *Abies lasiocarpa* zones, (2) its average July temperatures are similar to those of the *Pseudotsuga* and *Abies* zones, (3) its average annual precipitation is similar to that of the *Pseudotsuga* and *Abies* zones, and (4) its drought periods are similar to those of the *Pseudotsuga* and *Abies* zones. Environmental factors other than temperature and precipitation—perhaps wind, snow cover, soil characteristics, or fire—must allow fescue grasslands to dominate the sites they do.

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